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BURNING INDEX RATINGS IN FIRE CONTROL PLANNING

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U. S. DEPARTMENT OF AGRICULTURE
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U. S. Department of Agriculture, Forest Service

Lake States Forest Experiment Station [1]

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BURNING INDEX RATINGS IN FIRE CONTROL PLANNING

by J. A. Mitchell

Fire-weather records hold the answers to many of our fire control problems. Systematic analysis of such records, however, is necessary to make available the information they contain. As an example of what can be learned from such an analysis, a summary of a study recently made for the Chippewa National Forest is of interest.

The Normal Fire Load

Based on 16 years' record (1936-51) for the period from April 1 to October 31 (the normal fire season), the Chippewa averaged 23.4 fire days a year, 43.9 fires, 609 acres burned, and an overall fire size of 13.9 acres. For the same period it averaged 40.1 safe days a year, 32.3 very low, 38.0 low, 40.8 moderate, 32.7 high, 24.6 very high, and 5.5 extreme. For planning purposes days rating low and moderate may be considered as potential fire days, while days rating high and above, which account for 86.6 percent of the fires and 93.3 percent of the area burned, may be classed as acute. On this basis the Chippewa averages 78.8 potential and

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[1] Maintained by the U. S. Department of Agriculture, Forest Service, at University Farm, St. Paul, Minn., in cooperation with the University of Minnesota.

62.8 acute fire days a year. The average frequency and relative significance of each class of day is indicated in table 1.

Background

Fire-weather records have been kept on the Chippewa since 1936 and the severity of burning conditions rated daily on a hundred point scale by means of the Lake States Burning Index Meter. (See Fire Control Notes for July 1952.) In general, days rating 0-1 are considered safe, while burning conditions on days rating 2-3 are classed as very low; 4-6, low; 7-12, moderate; 13-24, high; 25-49, very high; and from 50 up, extreme. Fires occurring on safe to moderate days can, as a rule, be handled by the regular forest organization, while high, very high, and extreme days usually call for supplemental help in the way of seasonal fire guards, standby crews, and emergency labor. Normally, primary lookouts are manned when the burning index is 4 or above, secondary lookouts at 7, and the protection force is alerted when 12 is reached. Locally, these standards are modified if necessary to meet special conditions of risk (the chance of fires being started) and hazard (fuel conditions). Currently, burning index ratings serve as a guide for administrative action. Their role in protection planning, however, is equally important.

Table 1.--Summary of forest fire statistics by class of day (April 1-October 31), Chippewa National Forest, 1936-51

Item	Class of day							Total
	Safe 0-1	V.low 2-3	Low 4-6	Mod. 7-12	High 13-24	V.high 25-49	Ext. 50 up	
				16-year averages				
Days								
Number	40.1	32.3	38.0	40.8	32.7	24.6	5.5	214
Percent	18.7	15.1	17.7	19.1	15.3	11.5	2.6	100
Fire-days								
Number	0.2	0.4	1.4	3.3	6.1	8.4	3.6	23.4
Percent	.8	1.7	6.0	14.1	26.1	35.9	15.4	100
Percent of days in each burning index class on which fires occurred								
Percent	0.5	1.2	3.7	8.1	18.6	34.2	65.5	10.9
Fires								
Number	0.2	0.4	1.4	3.9	9.0	16.5	12.5	43.9
Percent	.4	.9	3.2	8.9	20.5	37.6	28.5	100
Area burned								
Acres	*	2.2	20.7	18.0	73.7	157.1	337.4	609.1
Percent	*	.3	3.4	3.0	12.1	25.8	55.4	100
Average number of fires per day**								
Number	*	0.01	0.03	0.08	0.24	0.69	2.28	0.21
Average size of fires**								
Acres	0.1	4.4	4.7	5.2	6.5	10.5	26.2	13.9
Average burn per day**								
Acres	*	0.1	0.2	0.6	1.9	6.3	67.5	2.8

* Less than 0.05
** Curved values

While averages provide a basis for planning, they can be misleading unless the extent and probable frequency of departures from them are taken into consideration. In the case of the number of days in each burning index class, for example, the record shows considerable variation from year to year (table 2). Since an average, plus and minus its standard deviation includes about two-thirds of the cases on which it is based, and twice the standard deviation includes approximately 95 percent, 2/ the first may be taken as the normal range while the latter indicates the extremes likely to be encountered (fig. 1). For example, the average number of extreme days a year on the Chippewa is 5.5 with a standard deviation of ± 3.4. Between 2.1 and 8.9 extreme days a year are, therefor, normally to be expected, while more than 12.3 extreme days in any one year are unlikely.

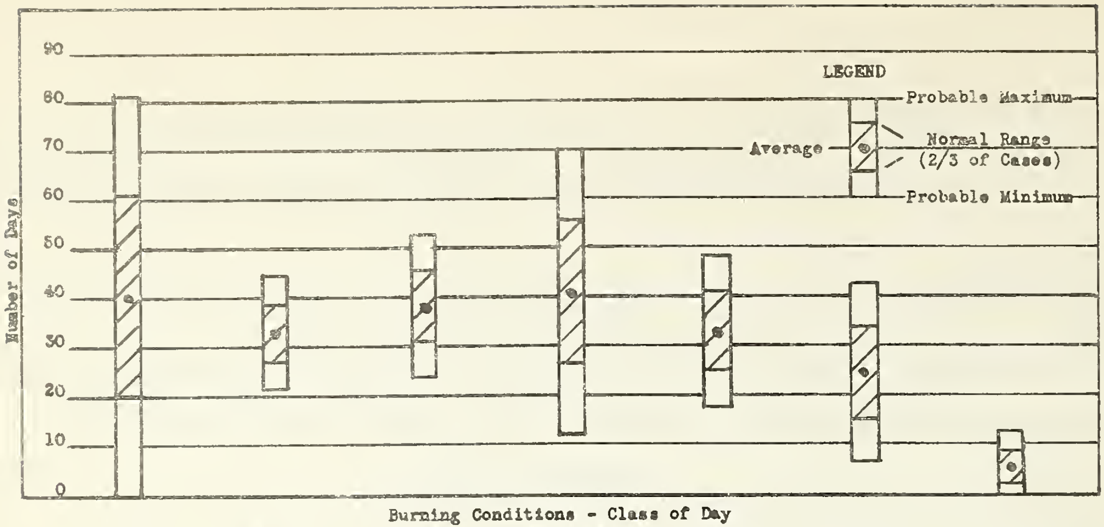
The average and its standard deviation also provide a measure of the calculated risk taken. For example, an organization based on the requirements of an average or normal year would be ample at least half of the time, while one based on the average number of potential and acute fire days plus their standard deviations should be adequate 5 years out of 6. On the latter basis, an organization capable of handling 88.7 potential and 74.2 acute fire days is called for on the Chippewa. So much for the overall picture.

2/ While strictly true only when the distribution is normal, the approximation is valid, in the present case, for all practical purposes since the data show a strong central tendency and such skewness as does prevail serves to increase the conservativeness of the estimate. In the present study, for example, more than half of the cases fall below the average, over 80 percent come within the normal range and approximately 95 percent are less than the average plus twice the standard deviation.

Table 2.--Number of days in each burning index class and relative severity by years, Chippewa National Forest, 1936-51 (April 1-October 31)

Year	Class of day							Relative severity
	Safe 0-1	V. low 2-3	Low 4-6	Mod. 7-12	High 13-24	V.high 25-49	Ext. 50-100	
				Number of days				Percent
1936	19	39	31	48	39	37	1	18.1
1937	19	28	39	71	32	20	5	16.6
1938	18	29	43	59	28	36	1	17.4
1939	16	39	40	42	31	40	6	20.1
1940	23	32	27	65	35	29	3	17.5
1941	42	42	31	46	40	12	1	12.5
1942	47	28	47	36	22	23	11	17.3
1943	38	24	49	33	39	22	9	17.9
1944	57	35	32	39	26	15	10	15.4
1945	49	22	43	45	35	14	6	14.7
1946	34	33	48	35	40	17	7	16.1
1947	44	31	42	32	41	22	2	14.7
1948	35	32	35	30	36	36	10	20.8
1949	39	28	41	32	35	31	8	18.8
1950	73	34	30	22	33	17	5	13.4
1951	88	41	30	18	11	23	3	11.2
Average	40.1	32.3	38.0	40.8	32.7	24.6	5.5	16.4
(s)	± 20.2	± 5.9	± 7.2	± 14.6	± 7.9	± 9.1	± 3.4	± 2.6

(s) Standard deviation



	Safe 0-1	Very Low 2-3	Low 4-6	Moderate 7-12	High 13-24	Very High 25-49	Extreme 50-up
Average	40.1	32.3	38.0	40.8	32.7	24.6	5.5
(s)	±20.2	± 5.9	± 7.2	±14.6	± 7.9	± 9.1	± 3.4

Figure 1: Number of Days in Each Burning Index Class - Chippewa N. F. (1936-1951) April 1 - October 31.

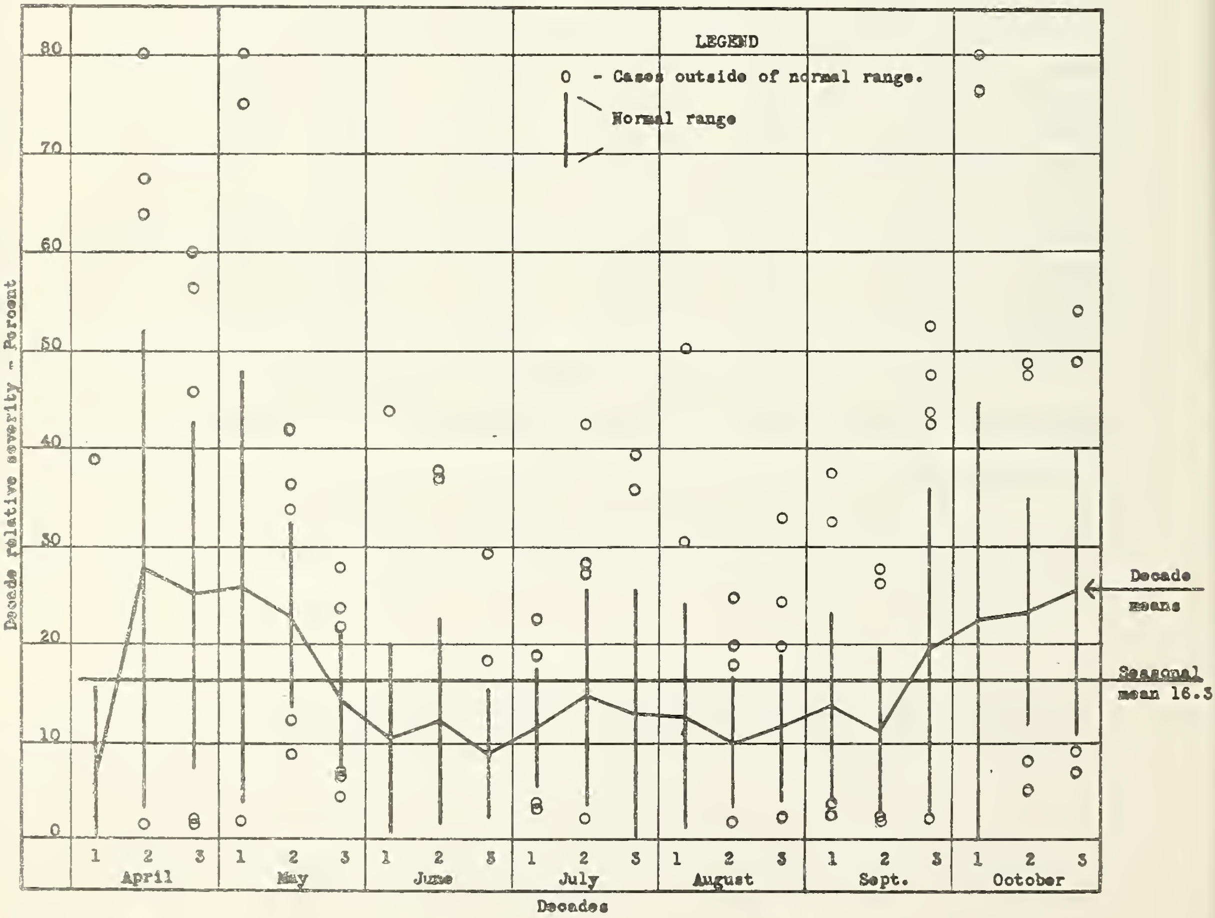


Figure 2: Seasonal distribution of burning conditions by decades - Chippewa N. F.

Seasonal Distribution of Burning Conditions

Since the fire season is not continuous or uniform, it is important in planning that the normal seasonal distribution of burning conditions as well as the probable variation from normal be known. To determine this, the mean relative severity (average burning index) and its standard deviation was determined for each 10-day period or decade [3] from April 1 to October 31. (See figure 2.) These calculations show that the mean decade relative severity is highest in spring and fall and lowest in early summer, and that the variation from normal tends to be greatest when the average relative severity is high.

While the period of acute burning conditions is normally confined to spring and fall, with the spring season the most severe, this pattern is occasionally upset by a wet spring followed by a dry summer or fall. Based on the relation of the decade means to the seasonal average, however, the periods from April 10 to May 20 and from September 20 to October 31 are most likely to be acute. The possibility of acute conditions at other times of year, however, should not be overlooked.

The significance of relative severity is indicated by the average number and average size of fires per decade (tables 3 and 4). For example, with a decade relative severity of 10, an average of 0.7 fires per decade averaging 1.5 acres in size can be expected, while with a decade relative severity of 40, an average of 6.4 fires averaging 8.9 acres are indicated. This, however, is only part of the picture.

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[3] Decades figured as running from 1 through 10, 11 through 20, and from the 21 through 30 or 31 of each month.

Table 3.--Average number of fires per decade for given decade relative severities - Chippewa National Forest

Relative 1/ severity	Plus units									
	0	1	2	3	4	5	6	7	8	9
	Average number of fires per decade									
0	0.0	0.0	0.05	0.1	0.15	0.2	0.3	0.4	0.5	0.6
10	.7	.8	.90	1.1	1.20	1.3	1.5	1.6	1.8	1.9
20	2.1	2.3	2.50	2.6	2.80	3.0	3.2	3.4	3.6	3.8
30	4.0	4.2	4.50	4.7	4.90	5.2	5.4	5.7	5.9	6.2
40	6.4	6.7	7.00	7.4	7.70	8.0	8.4	8.7	9.1	9.4
50	9.8	10.2	10.60	11.0	11.40	11.8	12.2	12.7	13.1	13.6
60	14.0	14.5	15.00	15.4	15.90	16.4	16.8	17.4	18.0	18.5
70	19.0	19.6	20.1	20.7	21.2	21.8	22.4*	23.0*	23.6*	24.2*

1/ Average maximum daily burning index for decade.

* Estimated.

Examples: With a relative severity of 30, the average number of fires equals 4.0.

With a relative severity of 35, the average number of fires equals 5.2.

Table 4.--Average size of fire in acres for given decade relative severities - Chippewa National Forest

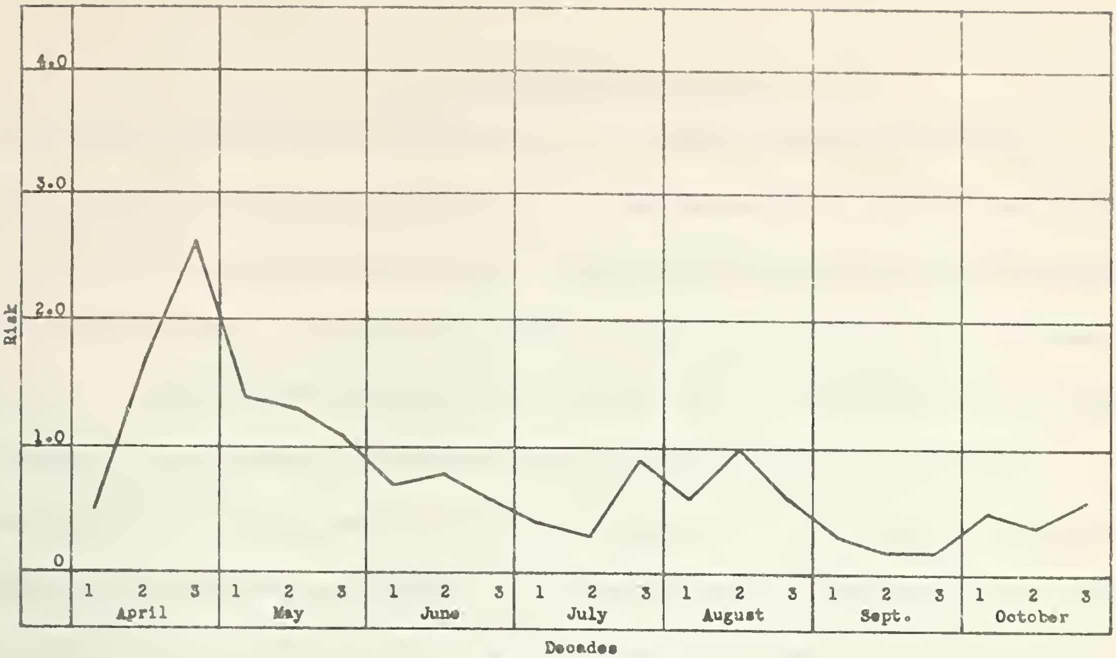
Relative 1/ severity	Plus units									
	0	1	2	3	4	5	6	7	8	9
	Average fire size - acres									
0	-	-	"Spot"		"A"	0.3	0.5	0.8	1.0	1.3
10	1.5	1.8	2.0	2.3	2.5	2.7	3.0	3.2	3.5	3.7
20	4.0	4.2	4.5	4.7	4.9	5.2	5.4	5.7	5.9	6.2
30	6.4	6.7	6.9	7.2	7.4	7.6	7.9	8.1	8.4	8.6
40	8.9	9.1	9.4	9.6	9.8	10.1	10.3	10.6	10.8	11.1
50	11.3	11.6	11.8	12.1	12.3	12.5	12.8	13.0	13.3	13.5
60	13.8	14.0	14.3	14.5	14.7	15.0	15.2	15.5	15.7	16.0
70	16.2	16.5	16.7	16.9	17.2	17.4	17.7	17.9	18.2	18.4

1/ Average maximum daily burning index for decade.

Examples: With a relative severity of 30, the average fire size equals 6.4 acres.
With a relative severity of 35, the average fire size equals 7.6 acres.

Seasonal Distribution of Risk

In general, risk or the chance of fires being started is determined by the use made of the area under protection and the habits and attitude of the users in regard to forest fires. On the Chippewa the outstanding causes of forest fires are debris burning and smoking. The result is a period of high risk in the spring, when most of the debris and meadow burning is done, and a relatively low risk in summer and fall, with a moderate increase during the summer vacation season and a slight rise during the hunting season in the fall. (See figure 3.) Correlation of number of fires per day with burning index and decade indicates the seasonal variation in risk and gives the correction factor for time of year to be applied to the average number of fires indicated by the decade relative severity. For example, the indicated average number of fires for a decade with a relative severity of 25 is three. During the first 10 days of May, however, the number of fires to be expected would be three times the risk factor 1.4, or a total of 4.2; while during the first 10 days of September only 0.9 of a fire (3 x 0.3) is likely, although the relative severity or degree of flammability prevailing is the same in both cases. This explains why on the Chippewa the burning index alone tends to underrate the fire load in the spring and overrate it in the summer and fall.



Decade risk factors:

0.5 1.7 2.6 1.4 1.3 1.1 0.7 0.8 0.6 0.4 0.3 0.9 0.6 1.0 0.6 0.3 0.2 0.2 0.5 0.4 0.6

Figure 3: Normal seasonal variation in risk (chance of fires starting) by decades - Chippewa N. F.

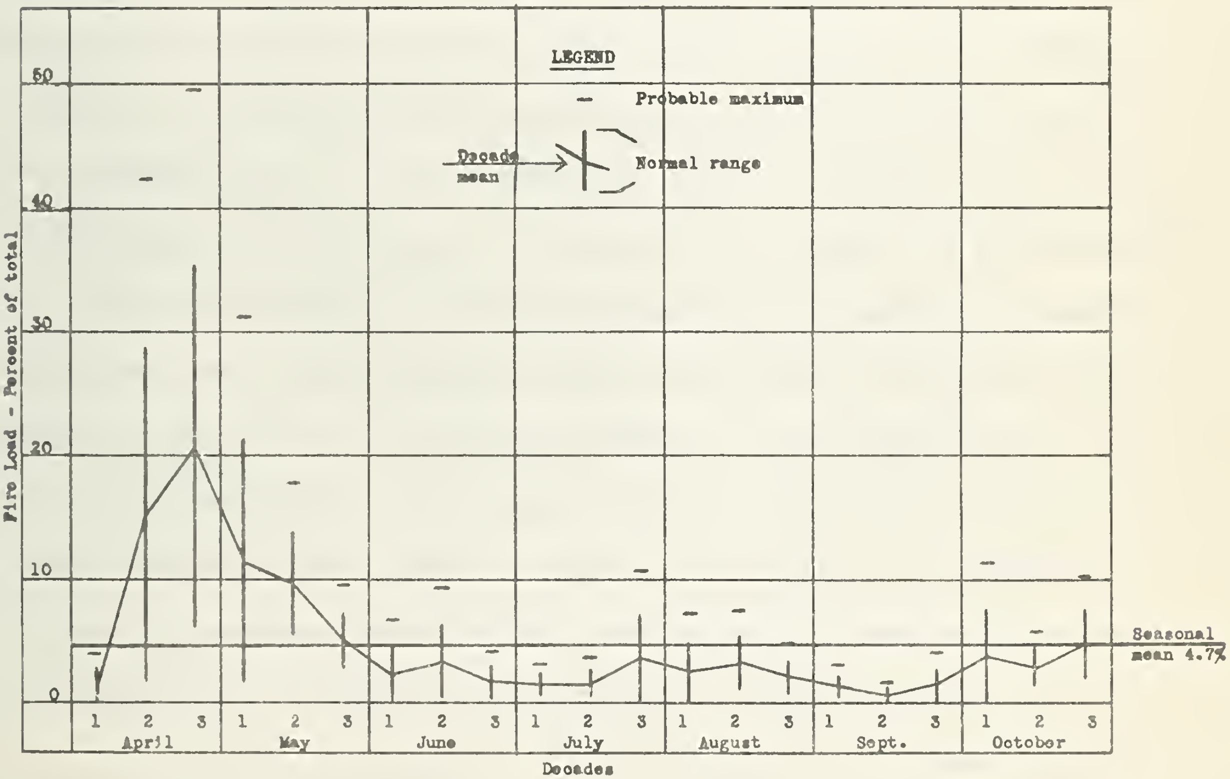


Figure 4: Normal seasonal distribution of fire load by decades - Chippewa N. F.

Normal Seasonal Distribution of Fire Load

Currently the fire load is determined by the severity of burning conditions and the risk prevailing. If protection units are to be compared, hazard or fuel conditions must also be considered, but, since hazard is not a seasonal variable, it may be omitted in determining the seasonal distribution of fire load for a given protection unit.

Essentially, burning conditions indicate the degree of flammability prevailing and risk, the probability of fire occurrence. In effect, one tends to augment or to offset the other. Together, however, they provide a measure of the current fire load.

In the present study, the average decade relative severities were multiplied by the average decade risk factors and the products divided by their total to determine the normal seasonal distribution of fire load in percent. (See figure 4.) The result shows that normally on the Chippewa the fire load is high in the spring and low the balance of the seasons with only a moderate increase in summer and fall. Percentagewise, 63.3 percent of the total fire load normally occurs in April and May, 11.4 percent in October, and 9.3 percent between July 20 and August 20. The normal variation in fire load is also greatest during these periods as well as the possibility of extreme conditions. The indicated distribution of the fire load would, therefore, appear to be a sound basis for planning the seasonal distribution of protection effort. Although acute conditions are unlikely late in June and early in July and September, the possibility of such conditions makes it necessary to be prepared on an emergency basis at all times.

Conclusions

The results of the present study obviously apply only to the Chippewa National Forest. The method used, however, is applicable wherever satisfactory burning index ratings and sufficient base data are available. The point is that burning index ratings are a useful tool in fire control planning. As pointed out, they not only serve to indicate the degree of flammability prevailing currently but also make it possible to evaluate risk and to determine the normal fire load and its seasonal distribution, while standard deviation provides a sound and convenient method of determining the variation from normal conditions to be expected and a basis for determining the intensity of protection effort called for.

Station Papers, 1946-1953

Number

*1 Revised forest statistics for the Lake States, 1945, by the Forest Survey Staff, R. N. Cunningham, Regional Director. Sept. 1946.

*2 Postwar problems of the cross tie industry in the Lake States, by Arthur G. Horn and Harold F. Scholz. Sept. 1946.

3 Estimating cull in northern hardwoods, by W. M. Zillgitt and S. R. Gevorkiantz. Nov. 1946.

4 The reforestation job in the Lake States - a new estimate, by Paul O. Rudolf. Nov. 1946.

5 Lake States Forests and the pulp and paper industry, by E. L. Demmon. Dec. 1946.

6 Some forest-wildlife problems in the Lake States, by Shaler E. Aldous. Jan. 1947.

7 Growth and yield of jack pine in the Lake States, by S. R. Gevorkiantz. May 1947.

*8 Spacing of young red pine, by F. H. Eyre and Paul J. Zehngraff. June 1947.

*9 How can research help the Michigan timber owner? by E. L. Demmon. June 1947.

10 Optimum economic stocking for northern hardwoods, by W. M. Zillgitt. March 1948.

11 Balsam fir seed - its characteristics and germination, by Eugene I. Roe. March 1948.

12 An improved increment-core method for predicting growth of forest stands, by S. R. Gevorkiantz and Lucille P. Olsen. July 1948.

13 Forestry situation in the Lake States, by E. L. Demmon. Sept. 1948.

14 Hybrid poplar planting in the Lake States, by Paul O. Rudolf. Dec. 1948.

15 Publications of the Lake States Forest Experiment Station, 1923-1948, by the Lake States Forest Experiment Station. Jan. 1949. Supplement No. 1 Dec. 1951.

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* Not available for distribution.

Station Papers, 1946-53
(Continued)

Number

16 Forest fire burning conditions in the Lake States, by John S. Crosby. March 1949.

17 Control of weeds in conifer nurseries by mineral spirits, by J. H. Stoeckeler. May 1949.

18 Winter injury and recovery of conifers in the upper midwest, by J. H. Stoeckeler and Paul O. Rudolf. June 1949.

19 The place of forestry in the economic development of the Park Falls area, Wisconsin, by Howard W. Mayne. July 1949.

20 Commodity drain from forests of the Lake States, 1948, by Arthur G. Horn. April 1950.

21 Size-class distribution in old-growth northern hardwoods twenty years after cutting, by F. H. Eyre and W. M. Zillgitt. July 1950.

22 Growth and yield of upland balsam fir in the Lake States, by S. R. Gevorkiantz and Lucille P. Olsen. July 1950.

23 Reforestation research findings in northern Wisconsin and upper Michigan, by J. H. Stoeckeler and G. A. Limstrom. Dec. 1950.

24 Reducing mortality in old-growth northern hardwoods through partial cutting, by F. H. Eyre and F. R. Longwood. April 1951.

25 Changes in forest conditions 1936-1949 north central Minnesota and Upper Peninsula of Michigan (A preliminary analysis), by R. N. Cunningham. July 1951.

26 Quality of logs and lumber obtained from an improvement cut in second-growth hardwoods in northern Wisconsin, by Carl Arbogast, Jr. Dec. 1951.

27 Reproduction on cut-over swamplands in the Upper Peninsula of Michigan, by Zigmond A. Zasada. Dec. 1952.

28 Burning index ratings in fire control planning, by J. A. Mitchell. Nov. 1953.